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ECMWF
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Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Seasonal to Decadal Prediction of fire danger

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Climate Prediction Group

Earth Sciences Department

Outline

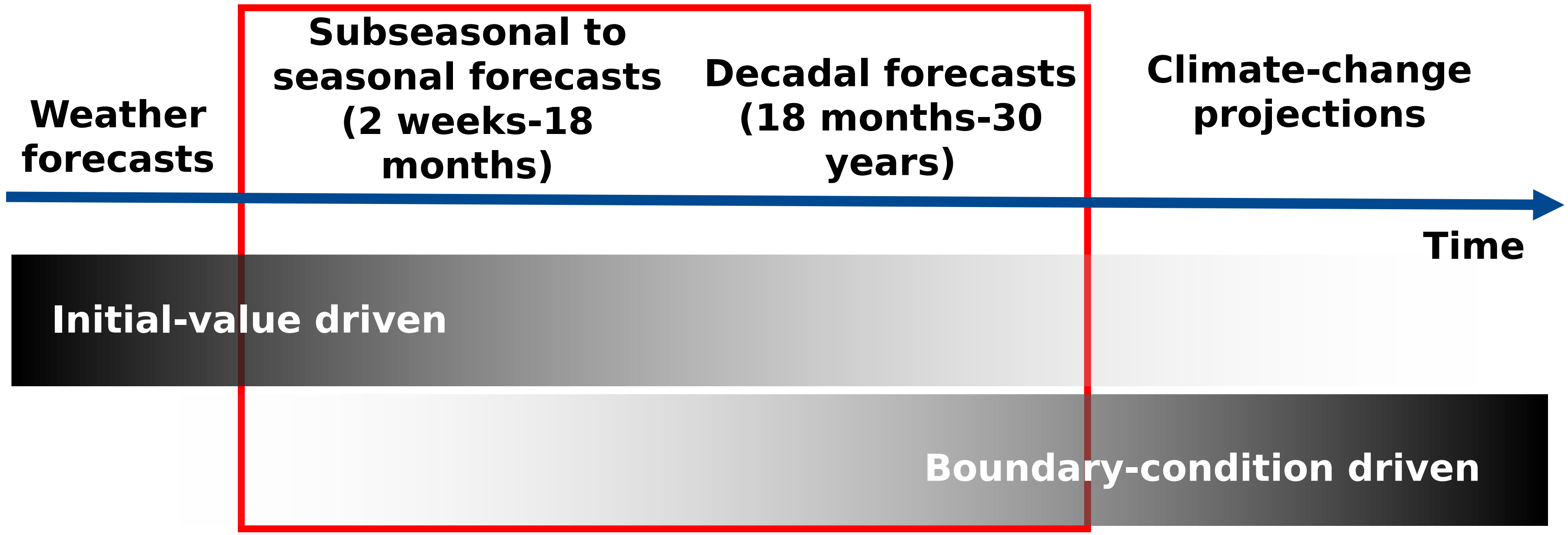
- Reasons for this visit at ECMWF
- Backgound on Seasonal-to-decadal climate predictions
- SPFireSD : Seasonal Prediction of Fire danger using Statistical and Dynamical models
- FWI-based seasonal prediction of fire danger

Outline

- Reasons for this visit at ECMWF
  - Primary motivation : seasonal prediction of fire danger using ECMWF S5 seasonal forecasts
  - Gain practical knowledge on the CALIVER analysis tools for visualization and calibration of FWI forecasts
  - Understand the workflow of ECMWF’s FWI forecasts (GEFF/EC-FIRE) and potentially expand it to seasonal timescales (research only for now)
  - Expand collaboration on seasonal (and decadal ?) prediction of fire danger

Climate prediction time scales

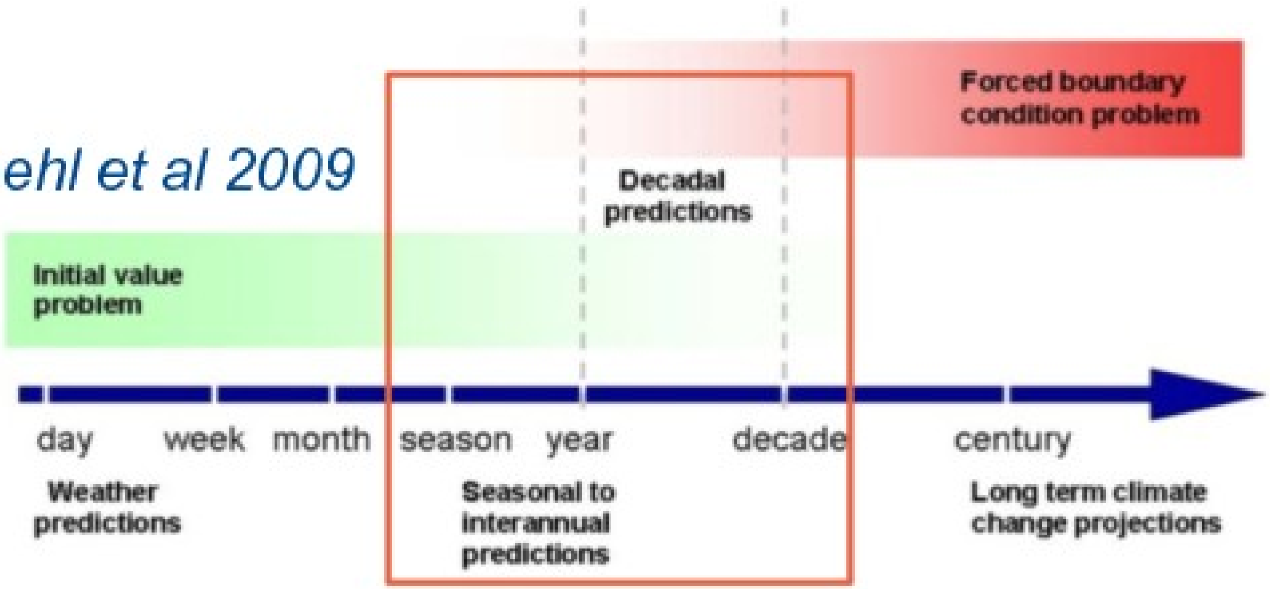
Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialization and systematic comparison with a simultaneous reference.



Adapted from Meehl et al. (2009)

Cornerstones of climate prediction

Meehl et al 2009



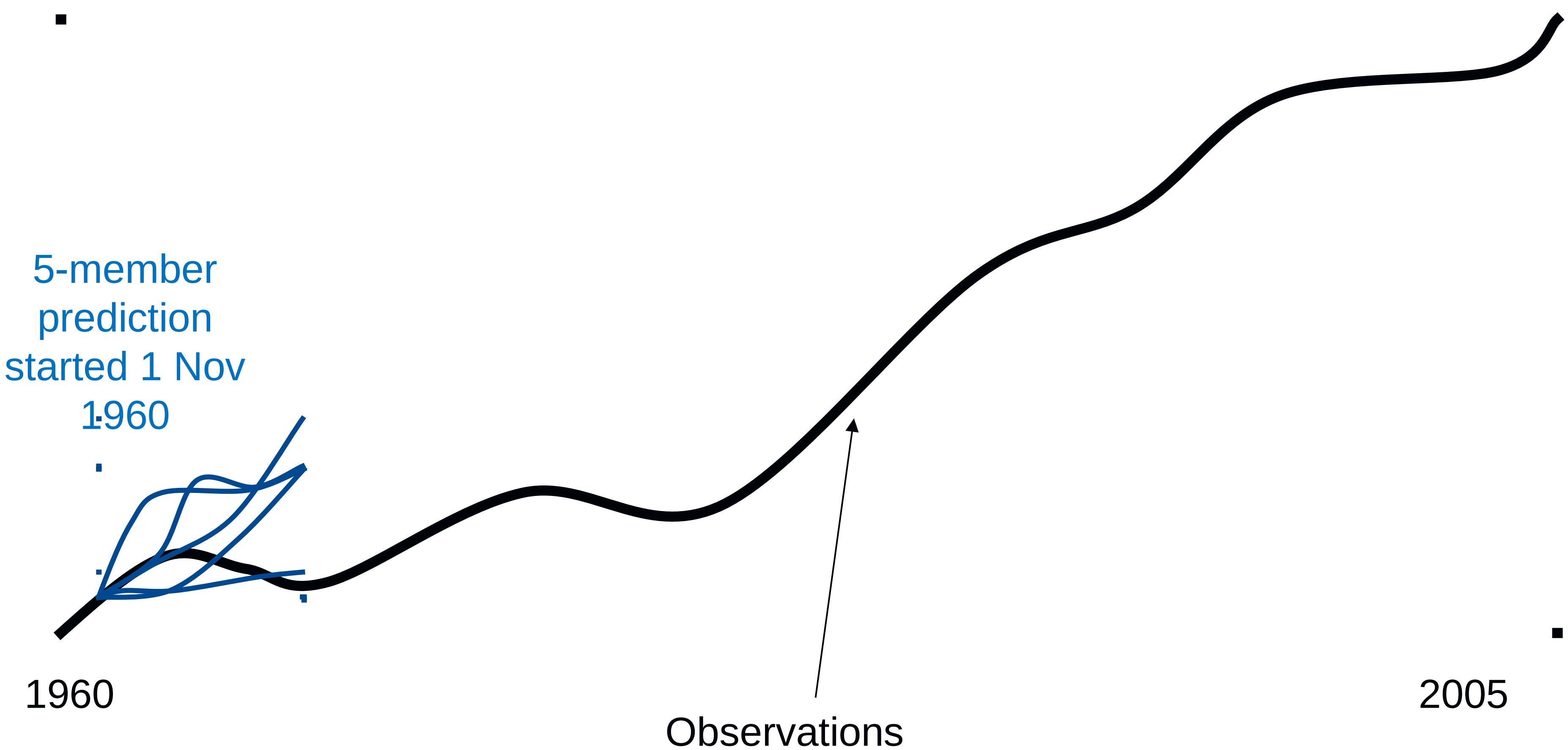
Scientific questions

1) Role of forcings?

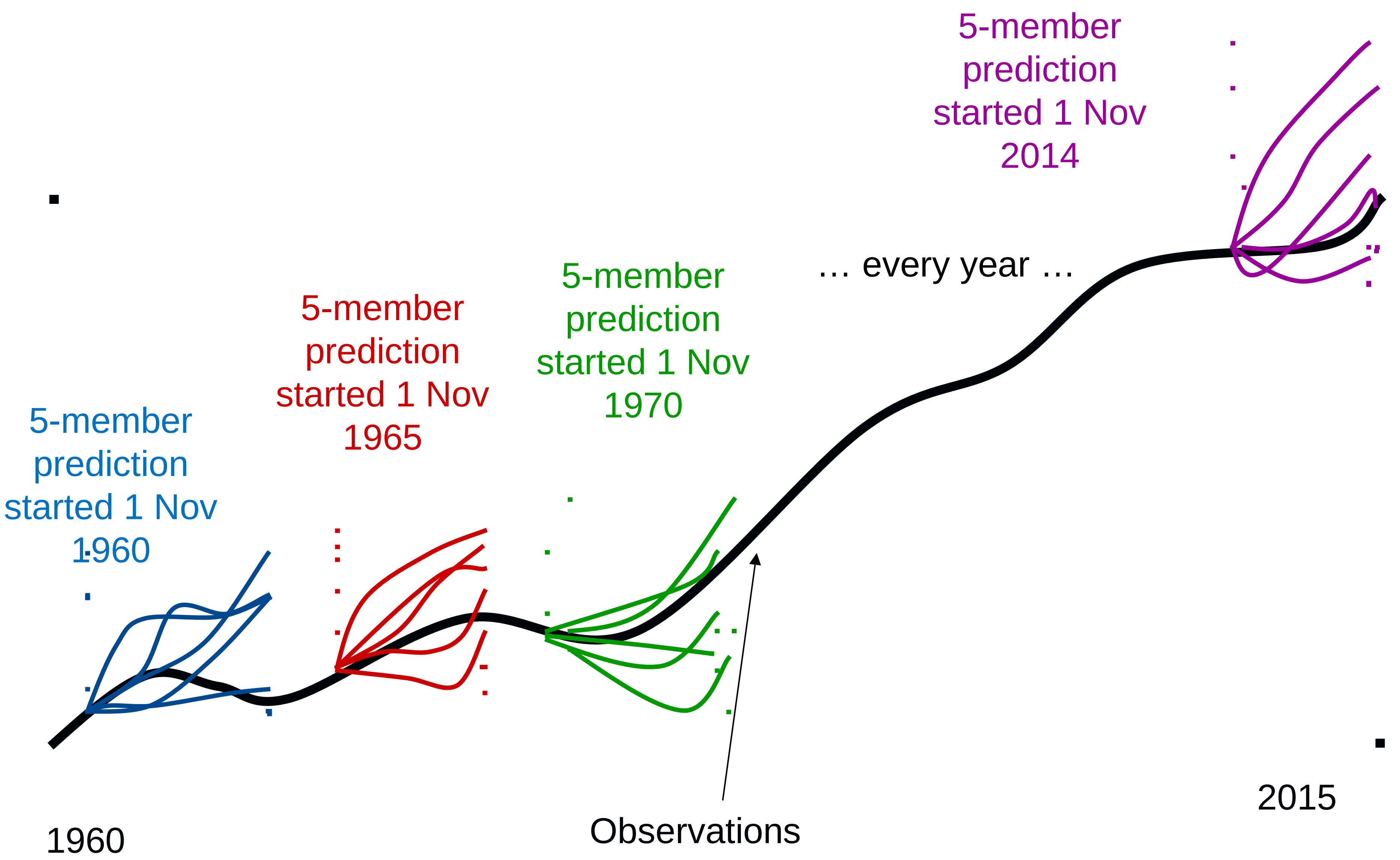
2) Internal sources of predictability?

3) Predictability of the different components?

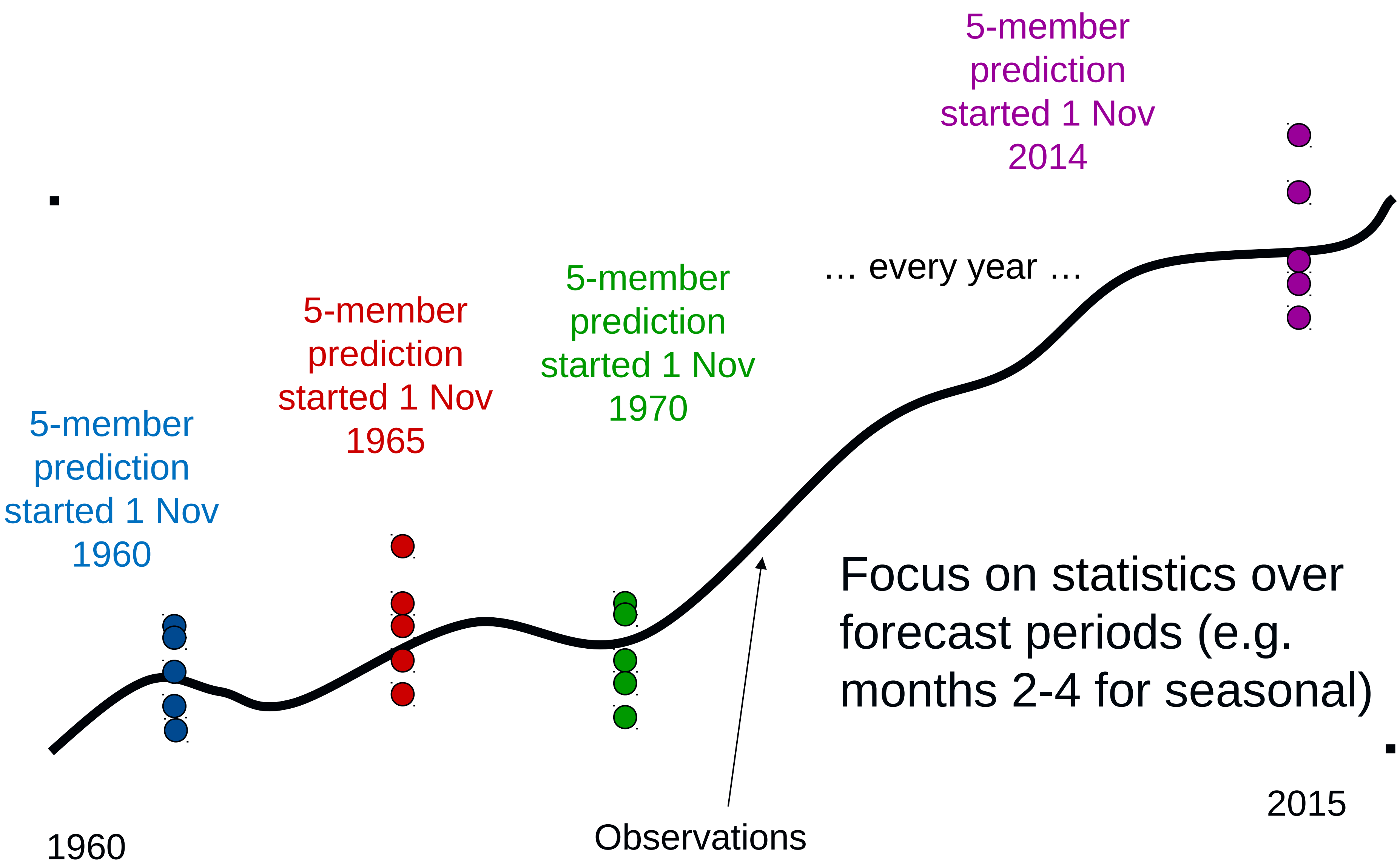
Climate prediction experiments



Climate prediction experiments



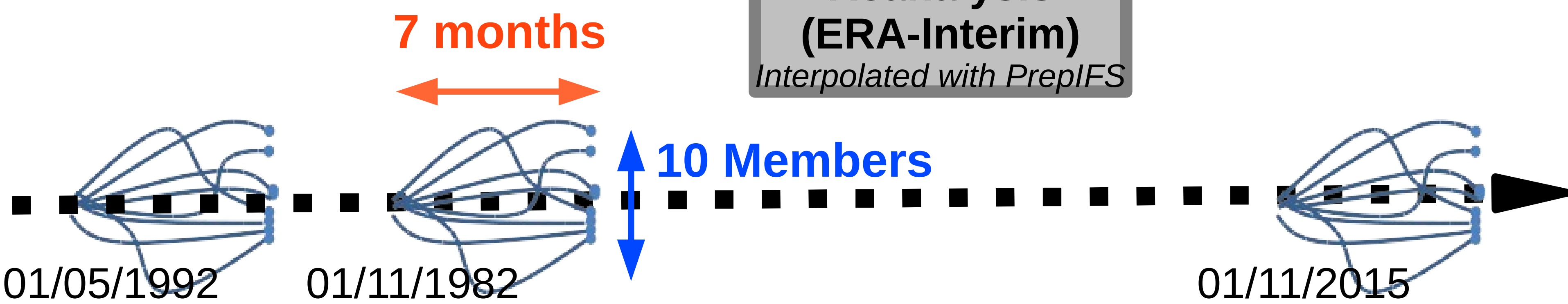
Climate prediction experiments



Focus on statistics over forecast periods (e.g. months 2-4 for seasonal)

Forecasts with EC-Earth 3.2.2

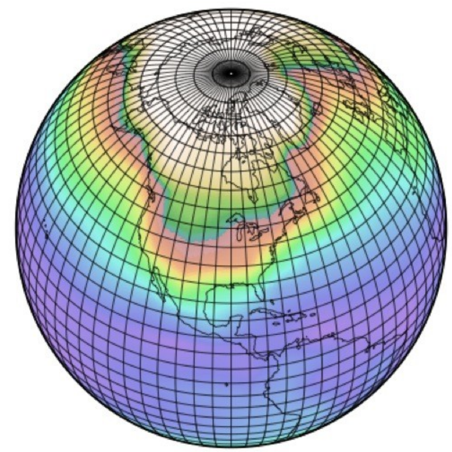
Atmosphere Reanalysis (ERA-Interim)
Interpolated with PrepIFS



Ice Reanalysis (IC3/BSC)
LIM3 forced by ERA-int with ocean nudged toward ORAS4

Ocean reanalysis (ORAS4)
Interpolated

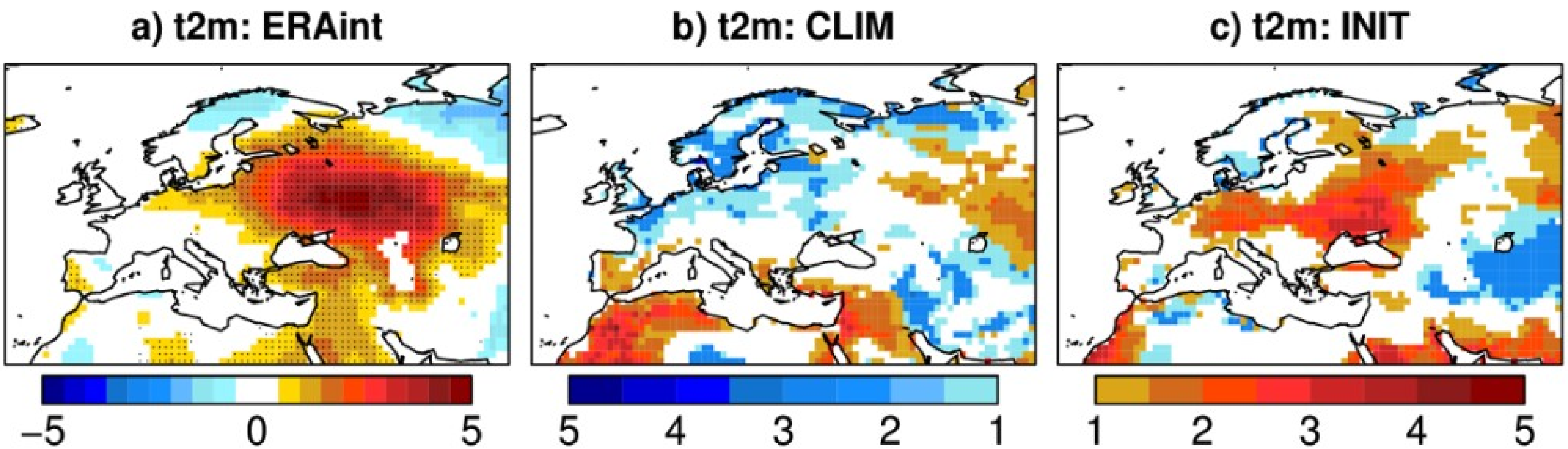
EC-Earth coupled model
- NEMO 3.6: ORCA1L75-LIM3
- IFS 36r4: T255L91
- Version 3.2.2



Land reanalysis (ERA-Land)

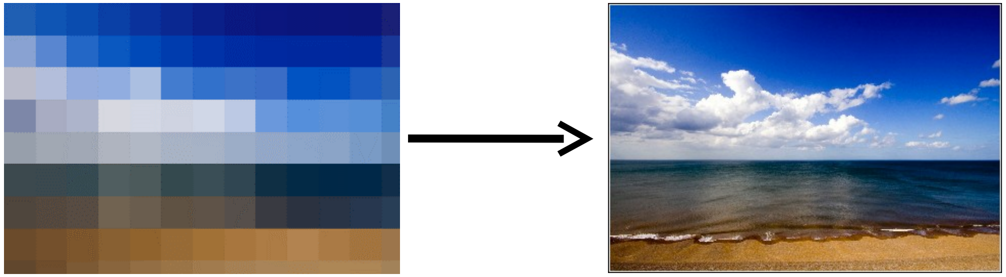
Impact of land surface initialization

JJA near-surface temperature anomalies in 2010 from ERAInt (left) and odds ratio from experiments with a climatological (centre) and a realistic (right) land-surface initialisation. Results for EC-Earth2.3 started in May with initial conditions from ERAInt, ORAS4 and a sea-ice



Similar results found for EC-Earth3 and high resolution (25 km).

Prodhomme et al. (2015, Clim. Dyn.)



Predictability from volcanic eruptions

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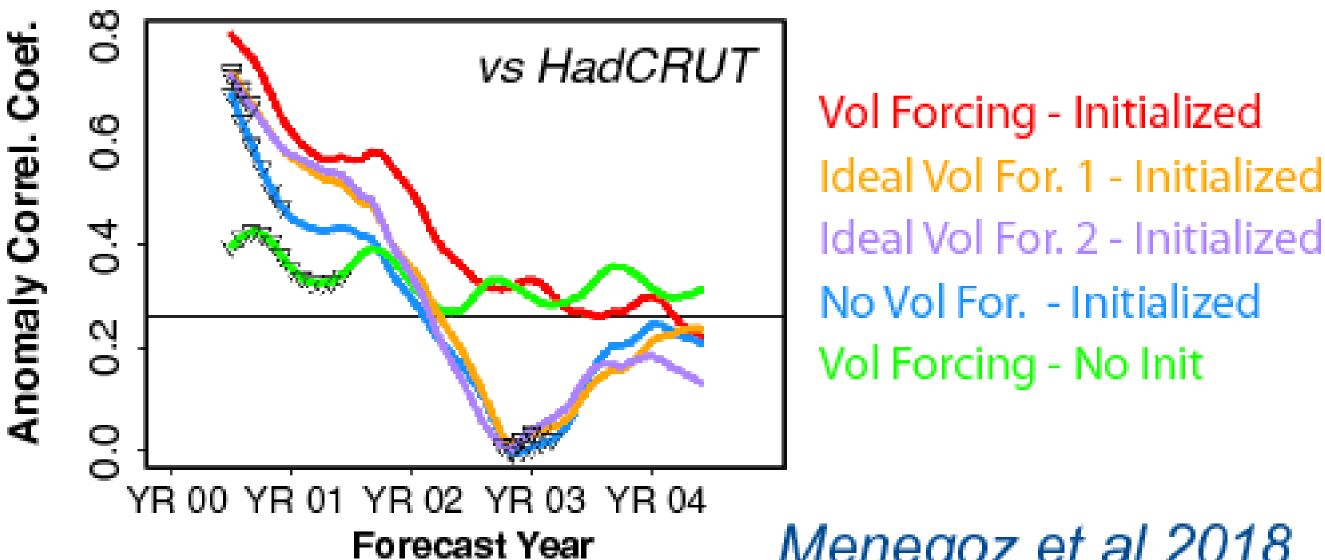
R. Bilbao
(roberto.bilbao@bsc.es)

Skill in mean global surface temperature



Menegoz et al 2018

Decadal Hindcasts
[1961-2001]

Major Eruptions:

Agung (1963)
El Chichón (1982)
Pinatubo (1991)

Volcanic eruptions can provide skill in mean global surface temperature for up to 2 years

DCPP – Decadal Climate Prediction

Yearly average 2M temperature skill

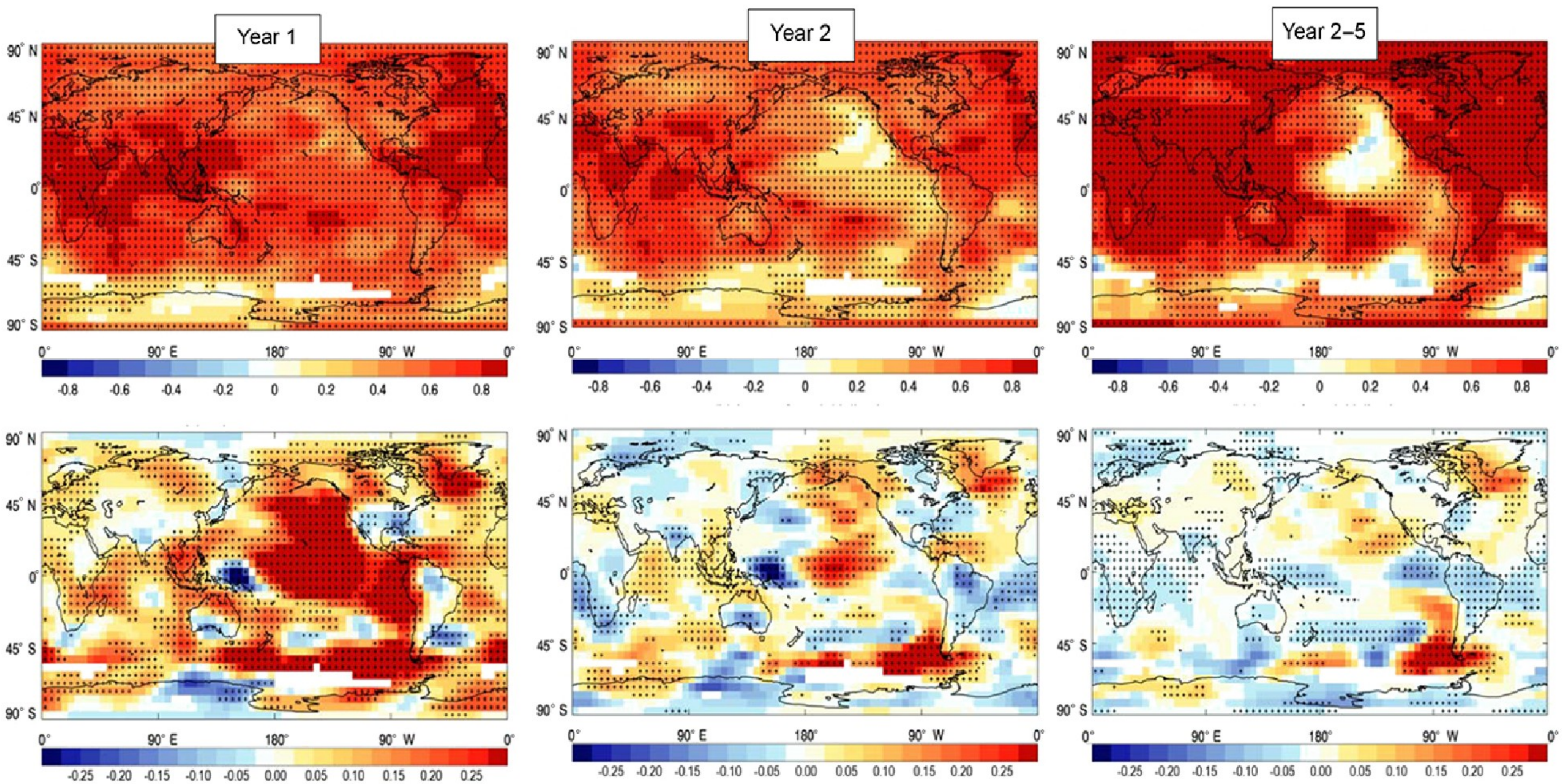


Figure 3. Correlation skill for Year 1, Year 2 and Year 2–5 forecasts of surface air temperature (upper panels). Impact of initialization (lower panels) based on the results from CanCM4, GFDL, MPI-ESL-LR, MIROC5, HadCM3 and the HadCM3 PPE hindcasts. Stippling denotes that the results are significant at the 10 % level (using a two-tailed test). Plots provided by R. Eade (private communication, 2016).

Boer et al, 2018 GMD

DCPP – Decadal Prediction at BSC

- Initial Conditions:
  - prepared by BSC (atmosphere, ocean, sea ice)
  - for all years 1960-present
  - 4 start dates : **November**, February, May, August
- Component A : Decadal hindcasts (6000 years)
  - Every year from 1960-present
  - Starting in November of every year
  - 10 members
  - 10 year predictions
- Component B : Semi-operational decadal forecast (100 years)
  - 10 years x 10 members

DCPP – Decadal Prediction at BSC

- Component C - Volcano effects on decadal prediction (M. Menegoz)
- Component C - Idealized impact of AMV/Pacemaker experiments, also for PRIMAVERA (R. Bolbao)
- Carbon cycle :
  - LPJ-Guess for seasonal-to-decadal prediction of fire danger and carbon uptake (E. Tourigny)
  - PISCES for ocean CO2 uptake (V. Sicardi, R. Bernardello)
- seasonal prediction hindcasts
  - Use the first months of the decadal runs initialized in November
  - Run short (4 month) predictions initialized in February, May, August
- High Resolution Hindcasts (optional, 3000 years)
  - 5 members, after we have completed everything else (HiResMIP and DCPP standard)

DCPP – Decadal Prediction at BSC

- Decadal prediction of fire risk (E. Tourigny)
  - Decadal predictions initialized on Jan 1st for each year
  - Using daily IFS outputs from DCPP runs (temp, precip, radiation, etc.)
  - LPJ-Guess dynamic vegetation model and several wildfire models (SIMFIRE, SPITFIRE), forced with daily daily data from IFS predictions
  - Decadal prediction of carbon uptake
  - Possibly use the Fire Weather Index at the seasonal-to-decadal timescale

SPFireSD - Motivation

- Wildfires are the largest source of biomass burning (approximately 70% of global annual sources) and a great source of pollutants and atmospheric CO2
- In tropical areas such as the Amazon basin and Indonesia, wildfires are greatly affected by inter-annual fluctuations in tropical Sea Surface Temperatures (SSTs)
- The European countries most affected by wildfires are in the Mediterranean basin, with summer fires occurring during periods of drought.
- 2017 was a particularly extreme year for wildfires fire season with many deaths in Portugal and record-breaking wildfires in California.
- In light of this, seasonal prediction of wildfire danger appears as a priority for health, safety and economic welfare.
- While several short-term (up to 10 days in advance) fire danger systems are in place, there is currently no operational seasonal wildfire forecasting system for Europe and only a few for other continents

SPFireSD

- Seasonal Prediction of Fire danger using Statistical and Dynamical models (SPFireSD) is a MARIE SkŁodowska-CURIE ACTIONS Individual Fellowship (MSCA-IF)
- SPFireSD proposes to develop and assess seasonal fire prediction capability through a variety of complementary and innovative methods using statistical and dynamical models, with a focus on Europe, the Amazonian basin and Indonesia.
- This project will develop and assess seasonal prediction capability of wildfire danger using three complementary approaches:
  - 1) **Fire danger indices approach**: simple fire danger indices computed from seasonal dynamical climate prediction systems
  - 2) Statistical approach: statistical fire danger models using a combination of past observational data and seasonal dynamical climate forecasts
  - 3) **Dynamical approach: ensemble dynamical predictions** using state-of-the-art fire models within Earth System Models (LPJ-Guess part of the EC-Earth Earth System Model)

SPFireSD

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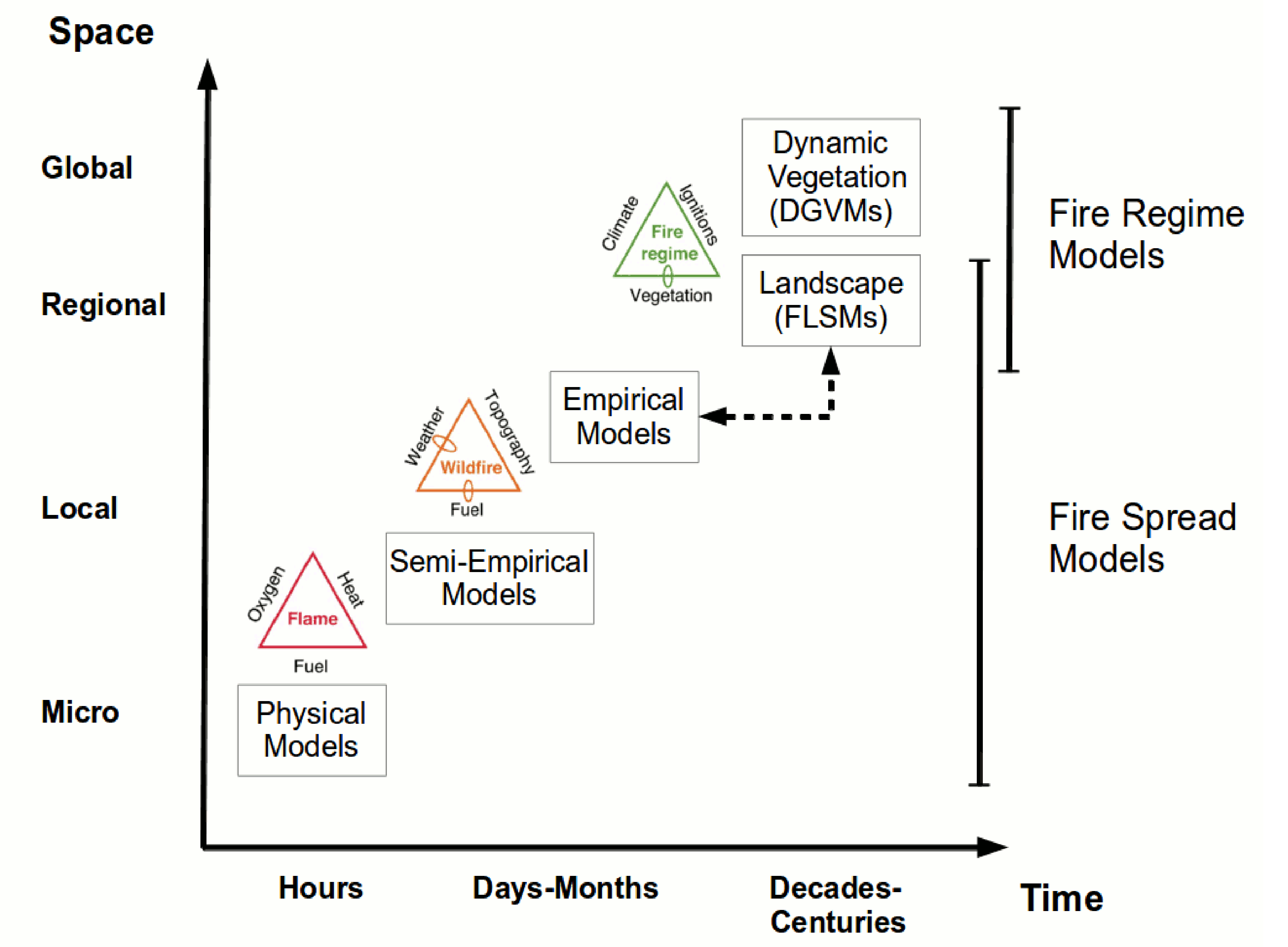
- WP1 Fire danger indices computed from seasonal dynamical climate prediction systems
  - This work package will rely on fire danger indices typically used for early warning in other countries and their computation requires climate variables which are available globally.
  - **Task 1.1 Validation of fire danger indices: Relationship between observationally-derived fire danger indices and fire danger**
  - Task 1.2 Fire danger indices obtained from dynamical seasonal climate prediction systems
- the European Forest Fire Information System (EFFIS) and Global Wildfire Information System (GWIS) produce 10-day forecasts of fire danger in Europe and globally using the Canadian Fire Weather Index and operational weather forecasts.
- This project aims to study the extension of the EFFIS/GWIS systems to seasonal timescales using predictions of FWI from multi-member operational seasonal prediction products .
- Visit to ECMWF in June to kick-start the work and foster collaboration.

Fire modeling across scales



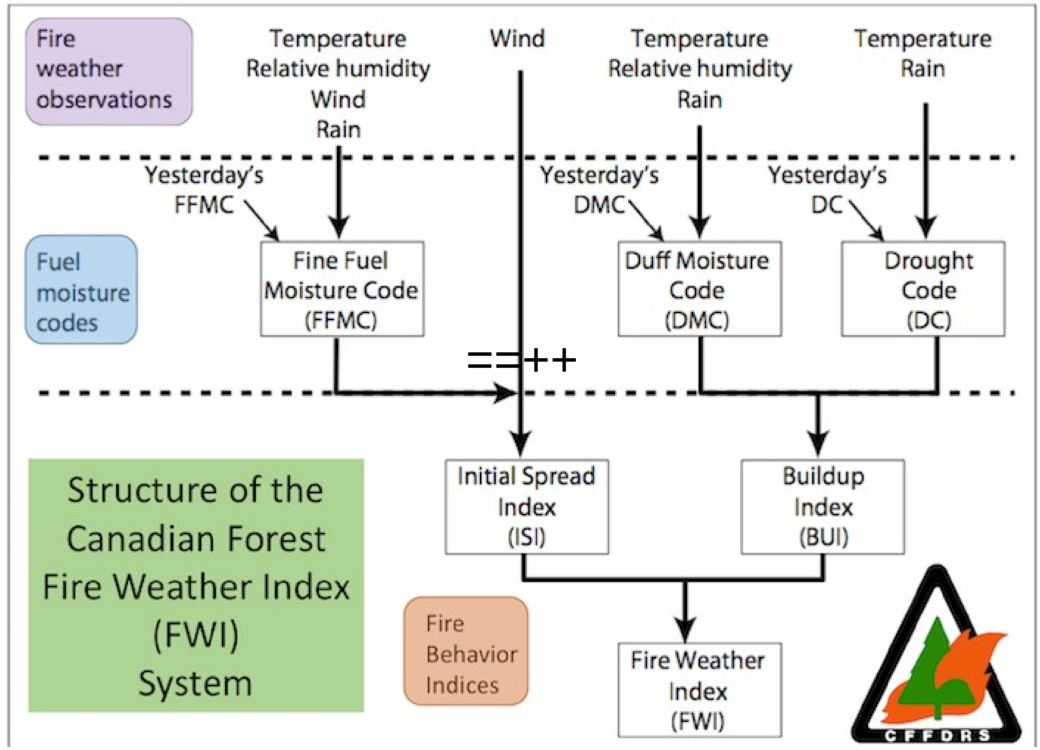
Canadian Fire Weather Index

The Canadian Fire Weather Index (FWI) is used operationally for short- and medium- term forecasting of fire danger in Canada.

It relies on daily observations of precipitation, temperature, wind and relative humidity at 12h local time.

It has been adopted by the (European Forest Fire Information System) EFFIS and Global Wildfire Information System (GWIS) for producing 10-day forecasts of fire danger in Europe.

However, these systems do not go beyond the 10-day short term forecast fimeframe.



(source: http://www.fbfrg.org/cffdrs/fire-weather-index-fwi-system)

Canadian Fire Weather Index

Fire Danger Ratings give you an indication of the consequences of a fire, if one was to start. The higher the fire danger, the more dangerous the conditions.

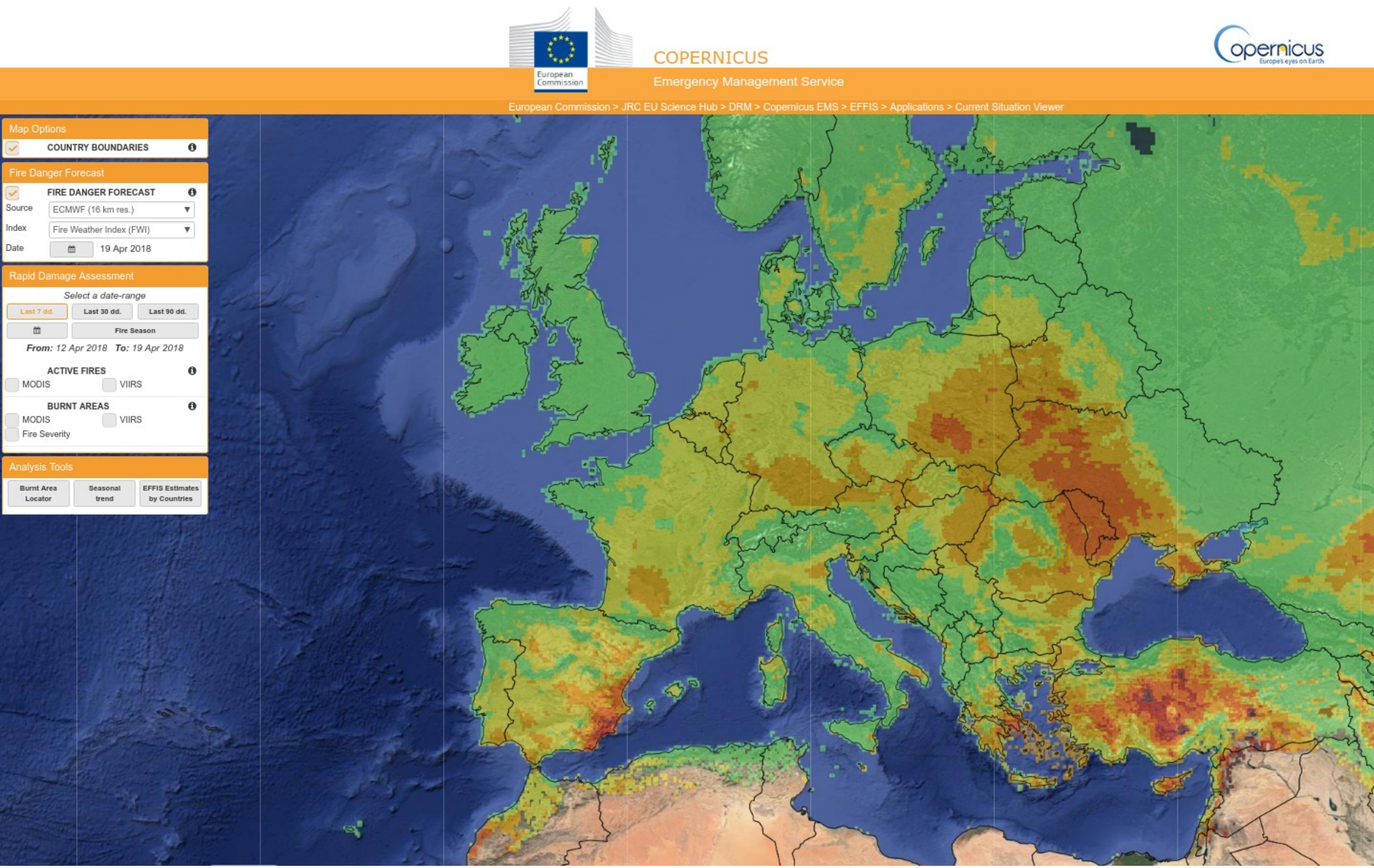
Fire Danger Ratings should be used as a trigger to take action to prevent or control a possible fire

Alexander, M.E.; De Groot, W.J. 1988. Fire behavior in jack pine stands as related to the Canadian Forest Fire Weather Index System. Canadian Forest Service, Northern Forestry Centre, Edmonton, AB. Poster with text.

Quintilio, D.; Fahnestock, G.R.; Dubé, D.E. 1977. Fire behavior in upland jack pine: the Darwin Lake Project. Canadian Forest Service, Northern Forestry Centre, Edmonton, AB. Information Report NOR-X-174.

Source : Francesca Di Giuseppe (ECMWF)
https://cpo.noaa.gov/Portals/0/Docs/MAPP/Pdfs/DiGiuseppe.pdf

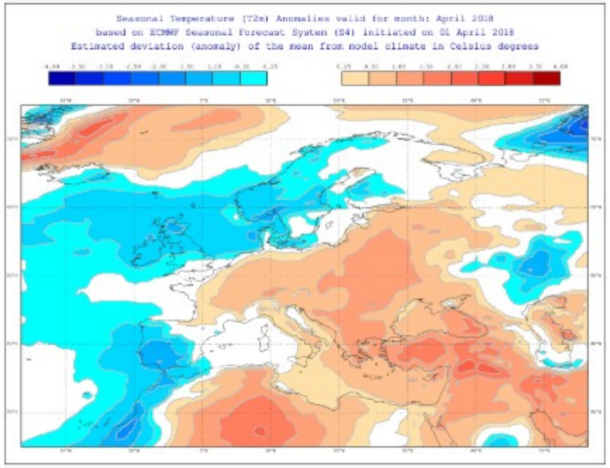
EFFIS 10-day FWI forecast



EFFIS seasonal prediction

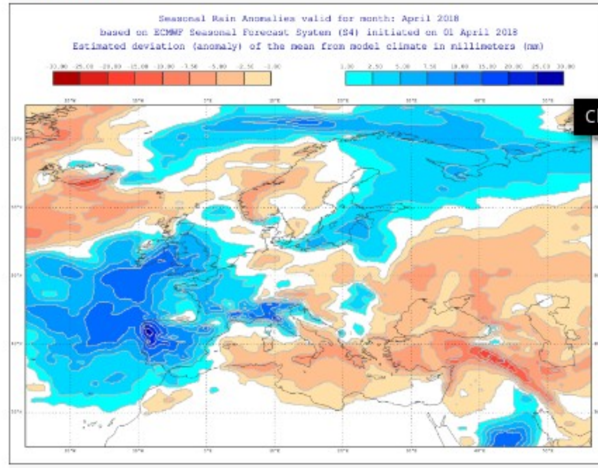
Temperature anomalies

APRIL 2018



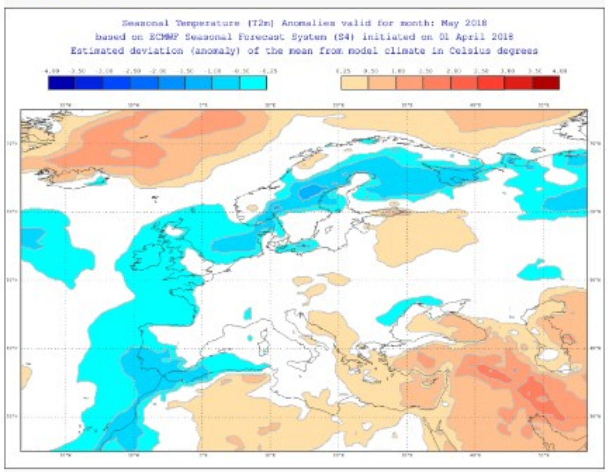
Rain anomalies

APRIL 2018



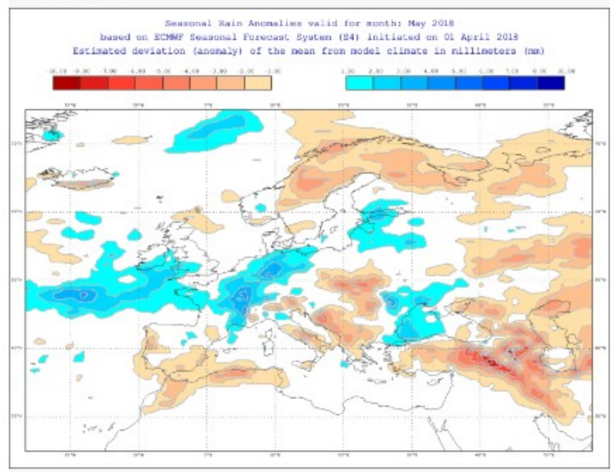
Temperature anomalies

MAY 2018



Rain anomalies

MAY 2018



FWI - Introduction

The 2017 fire season in California was the costliest on record, with 18 Billion US$ in damages, and deadliest with 43 casualties on record

REX/Shutterstock

FWI - Introduction

In October, around the Napa valley in Northern California, the Tubbs fire was the most destructive in US history. Warm temperatures and strong winds are thought to be responsible for the severity of these wildfires.

FWI - Introduction

In December, Southern California was plagued by severe wildfires and the Thomas fire near Los Angeles became the largest in California history. It was thought to be fueled by sever Santa Ana winds and warmer than average temperatures.

FWI - Introduction

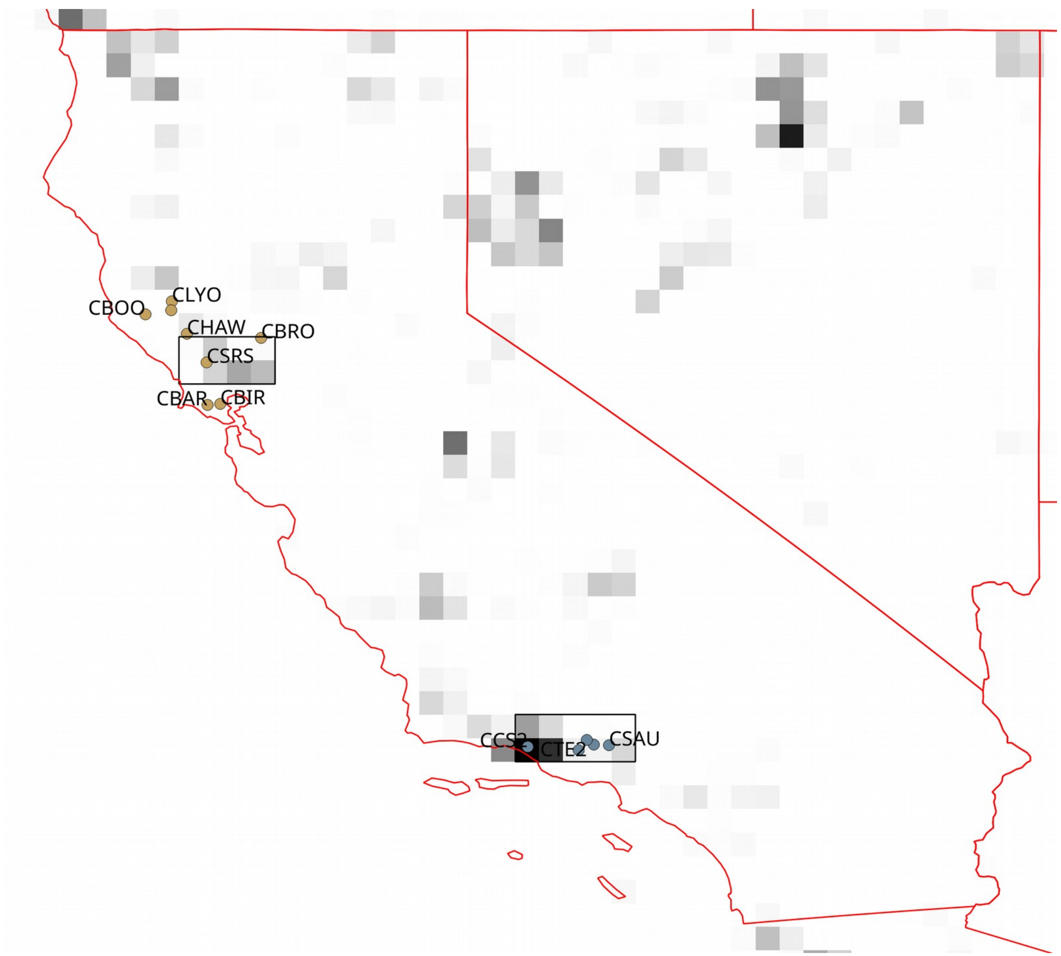
- What are the relative importance of climate (drought/heat waves) vs. weather events (dry spells, strong winds)?
- We use the Canadian Fire Weather Index to compute daily fire risk from daily observations of temperature, precipitation, wind speed and relative humidity.
- We study in which way the conditions of fall of 2017 were conductive to these extreme conditions, and if human-caused climate change could have contributed.

Data sources

- Burned Area data from the MCD64A1 global burned area product, aggregated at monthly 0.25deg grid.

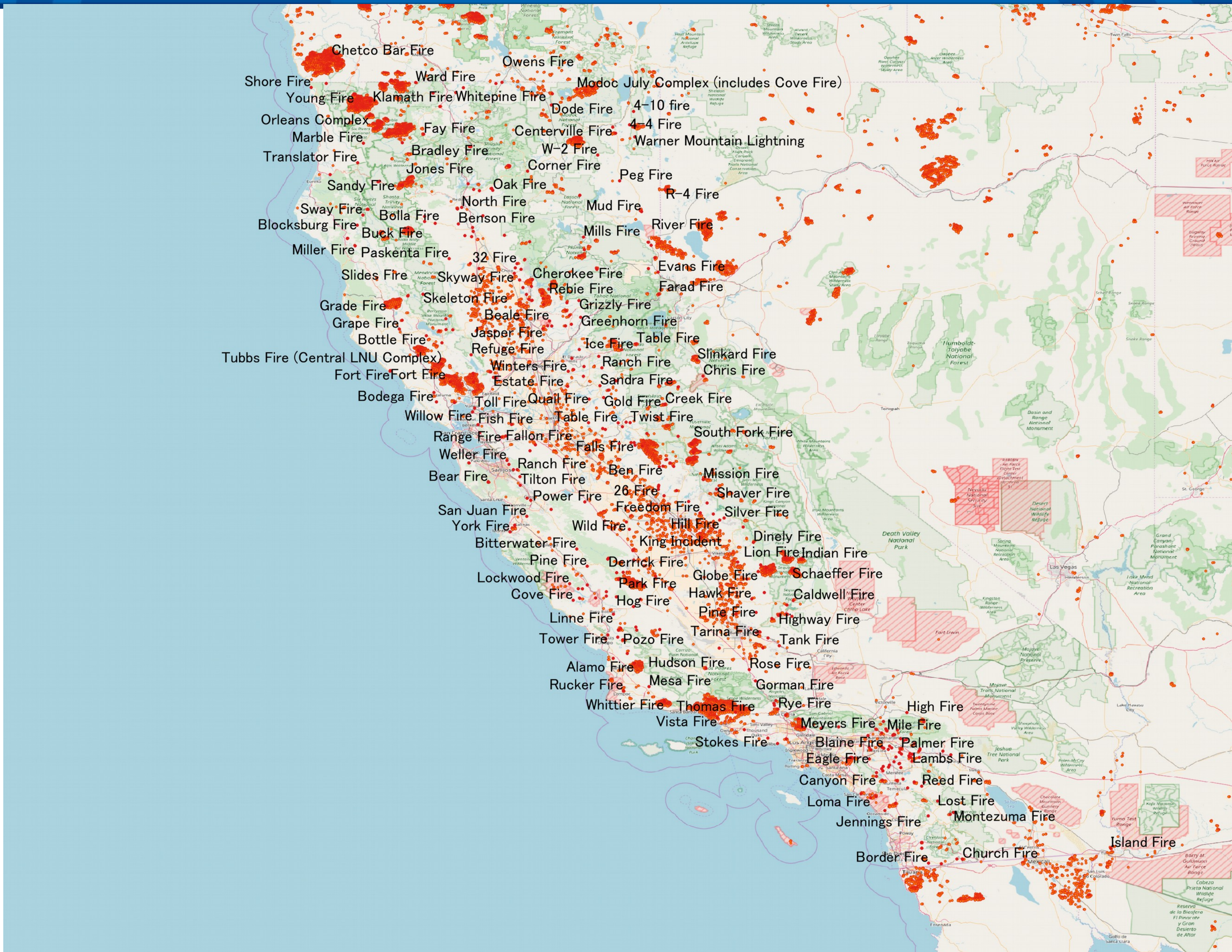
- daily weather data from Remote Automated Weather Stations (RAWS) located in the vicinity of the Tubbs fire (Northern California) e.g. CSRS - Santa Rosa California and Thomas fire (Southern California) e.g. CCS2 - Casitas California

- daily data from the ERA-Interim Reanalysis at native resolution (approx. 80 km) and North American Regional Reanalysis (NARR) interpolated to 0.25 degrees (approx. 30 km).



Overview of the study area showing Burned Area fraction during 2017 from the MCD64A1 burned area product and the RAWS stations used.

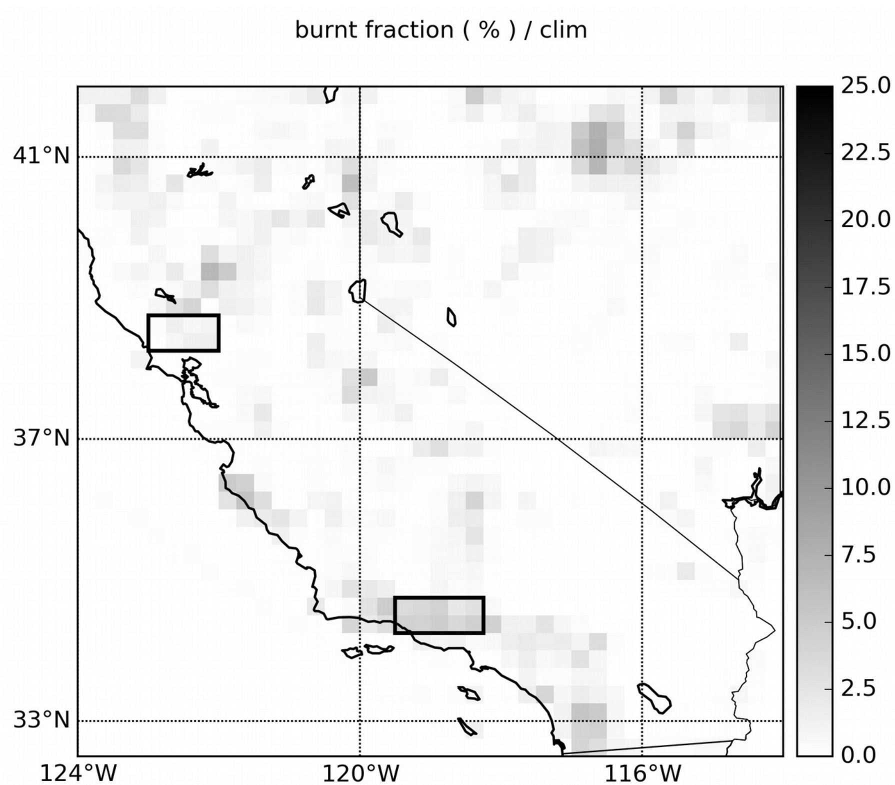
2017 California wildfires

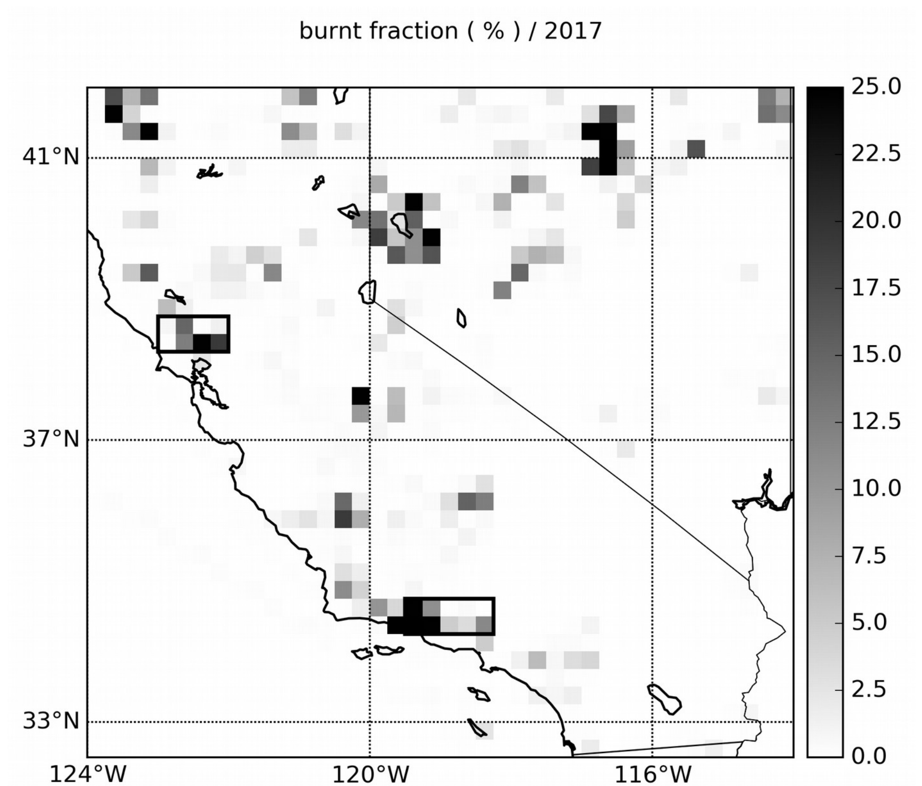


Results- was 2017 extreme?

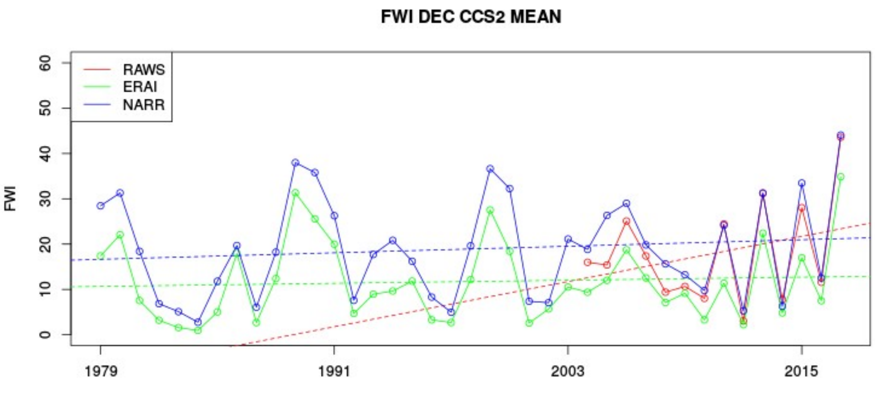
Observed burned areas in 2017 were indeed much higher than climatological averages.

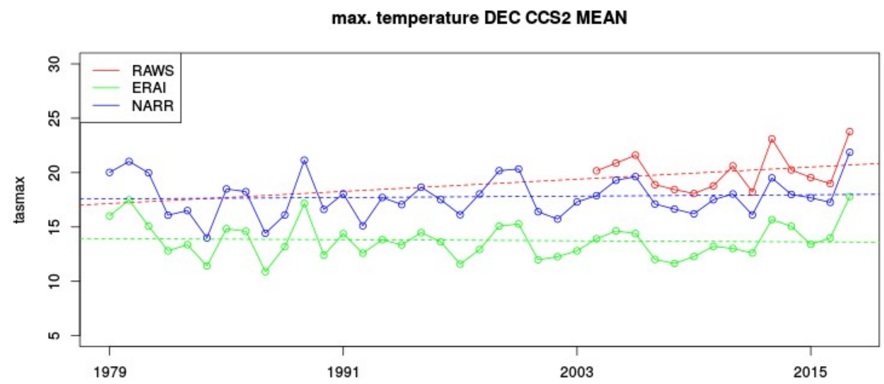
In fact many areas had not been previously burned in the entire MODIS observation period (2000-2017).

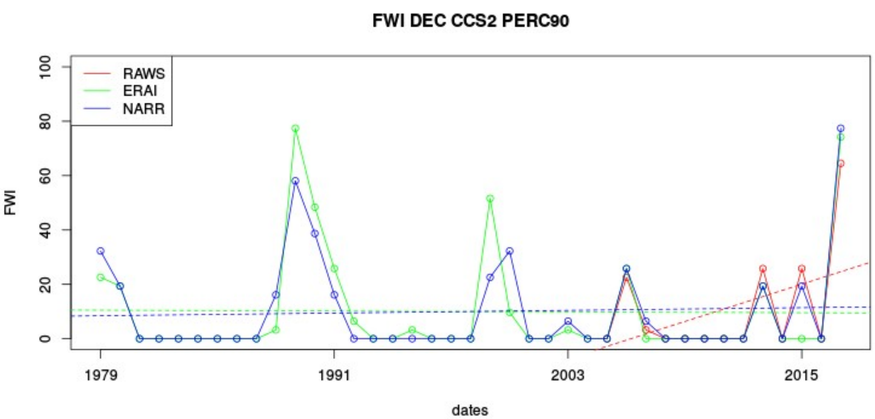


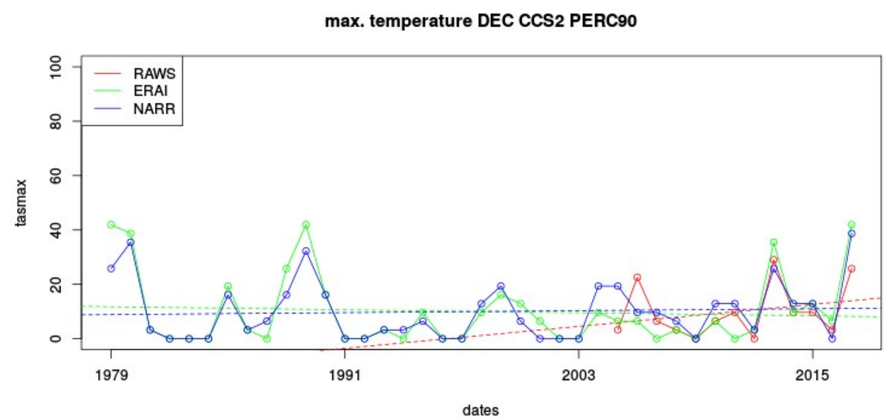


Results- was 2017 extreme?





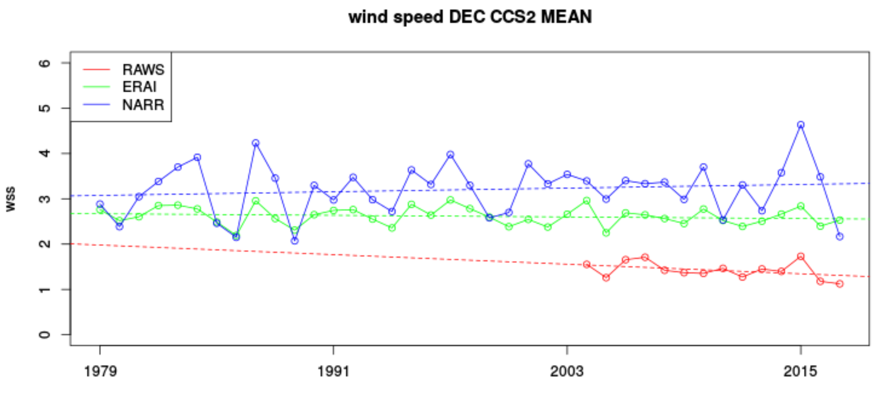


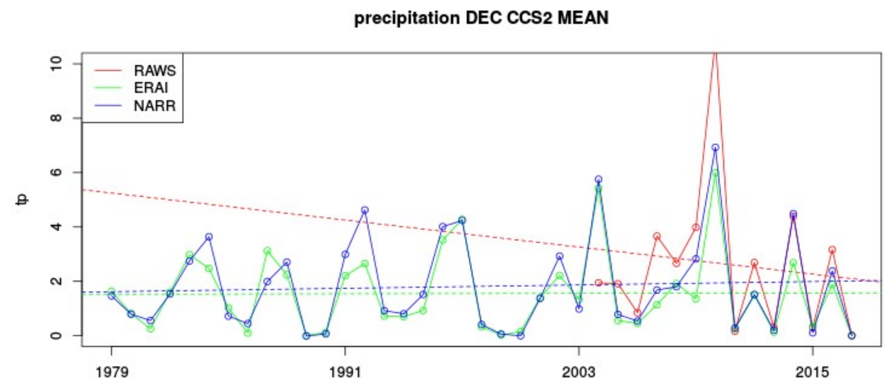


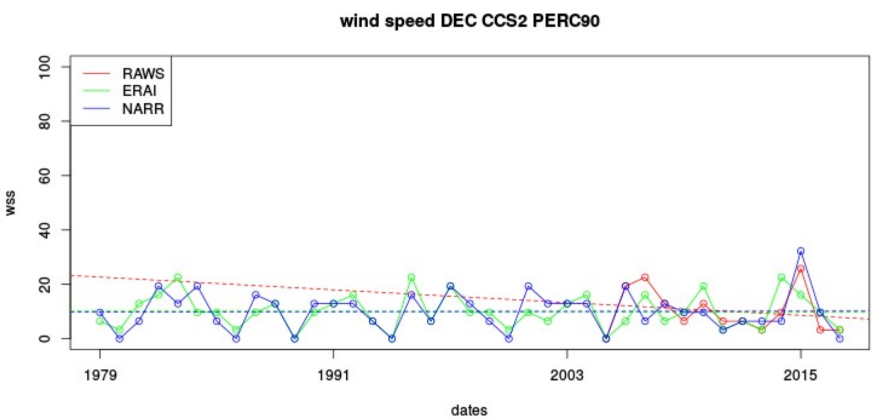
In December/2017 station and reanalysis data show that monthly-mean FWI was much higher than average and 80% of days were above the 90th percentile.

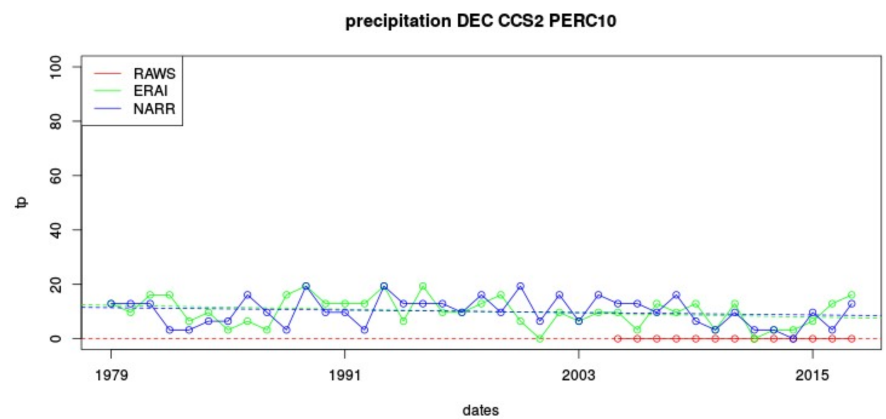
Maximum temperature was also above-average, and a linear trend of 0.05 C/year was detected, which is equivalent to 5C/century. The warming trend could be partially responsible for these extreme conditions (more work is needed).

Results- was 2017 extreme?







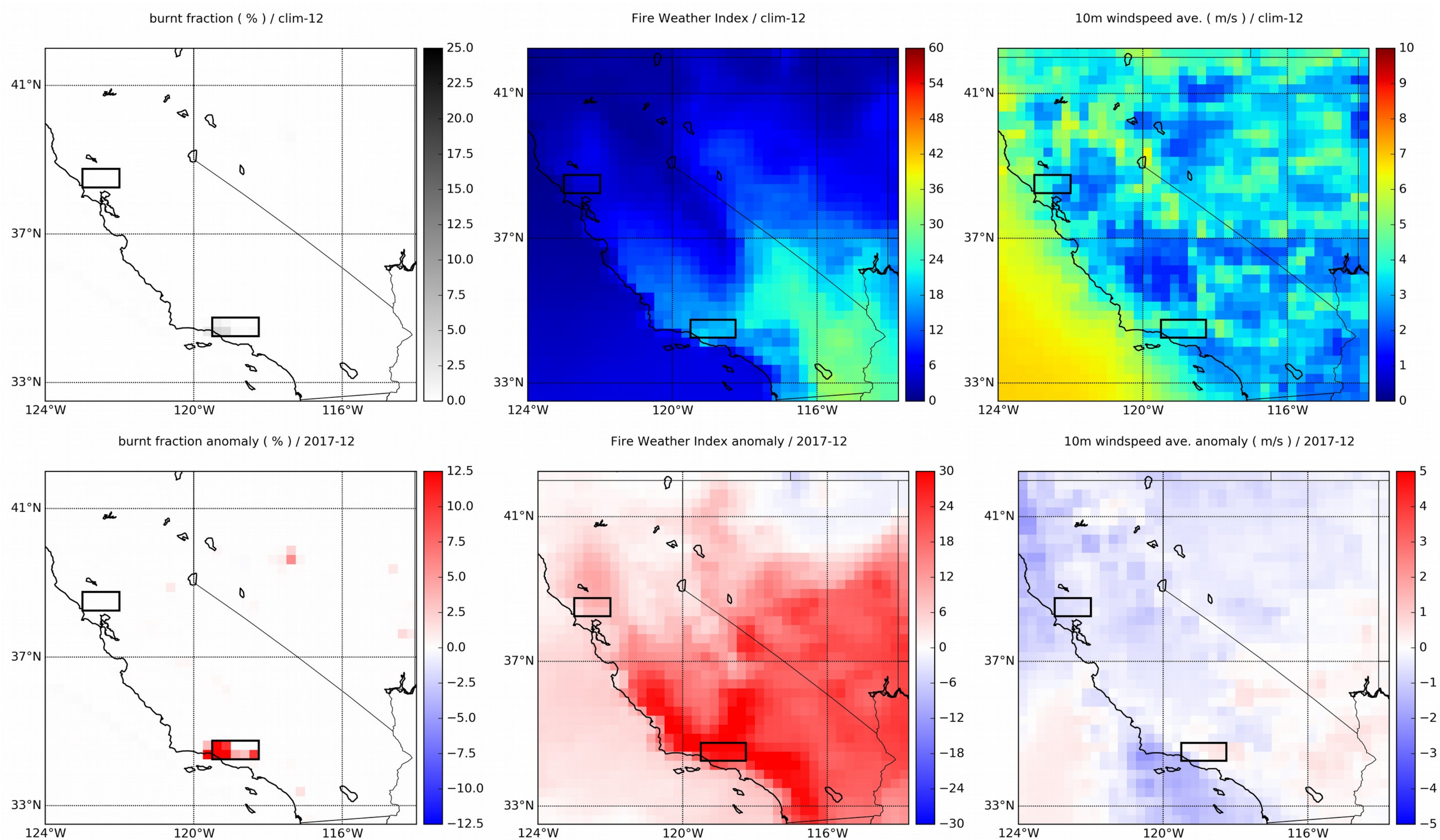


Despite news reports and statements that Santa Ana winds were exceptionally strong in Decembre/2017 we did not find such evidence in the station data.
In fact there were fewer strong wind events, but timing may be a factor.

Precipitation was below-average and which helped create dryer than average conditions.

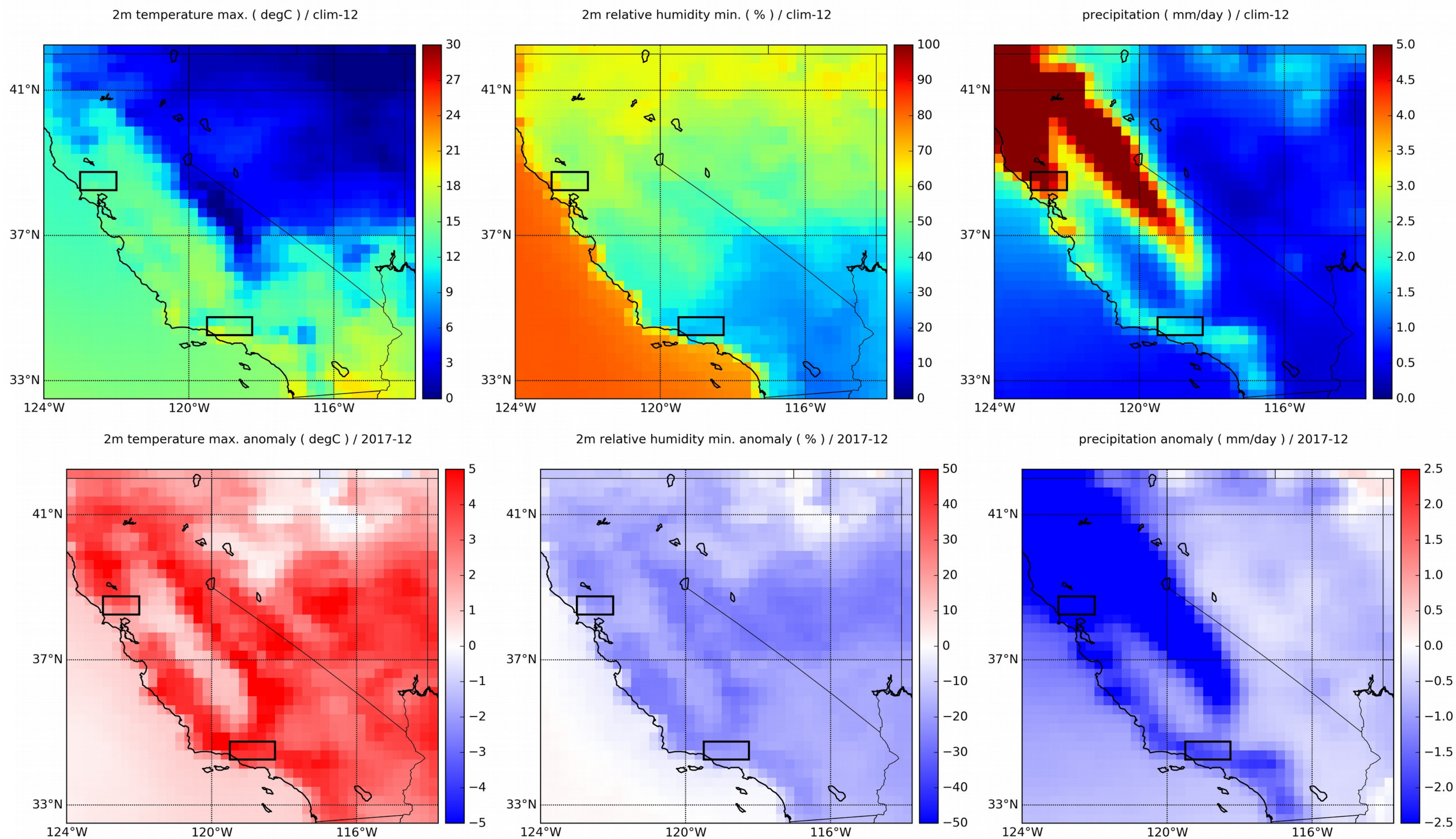
Results – FWI in December 2017

Anomalous burned area in Southern California associated with widespread anomalous FWI, but wind anomalies were not important.



Results – FWI in December 2017

However, extreme anomalies in temperature, relative humidity and precipitation were widespread. These long-lasting anomalies are identified as playing a key role.



Results – FWI in OCT-DEC 2017

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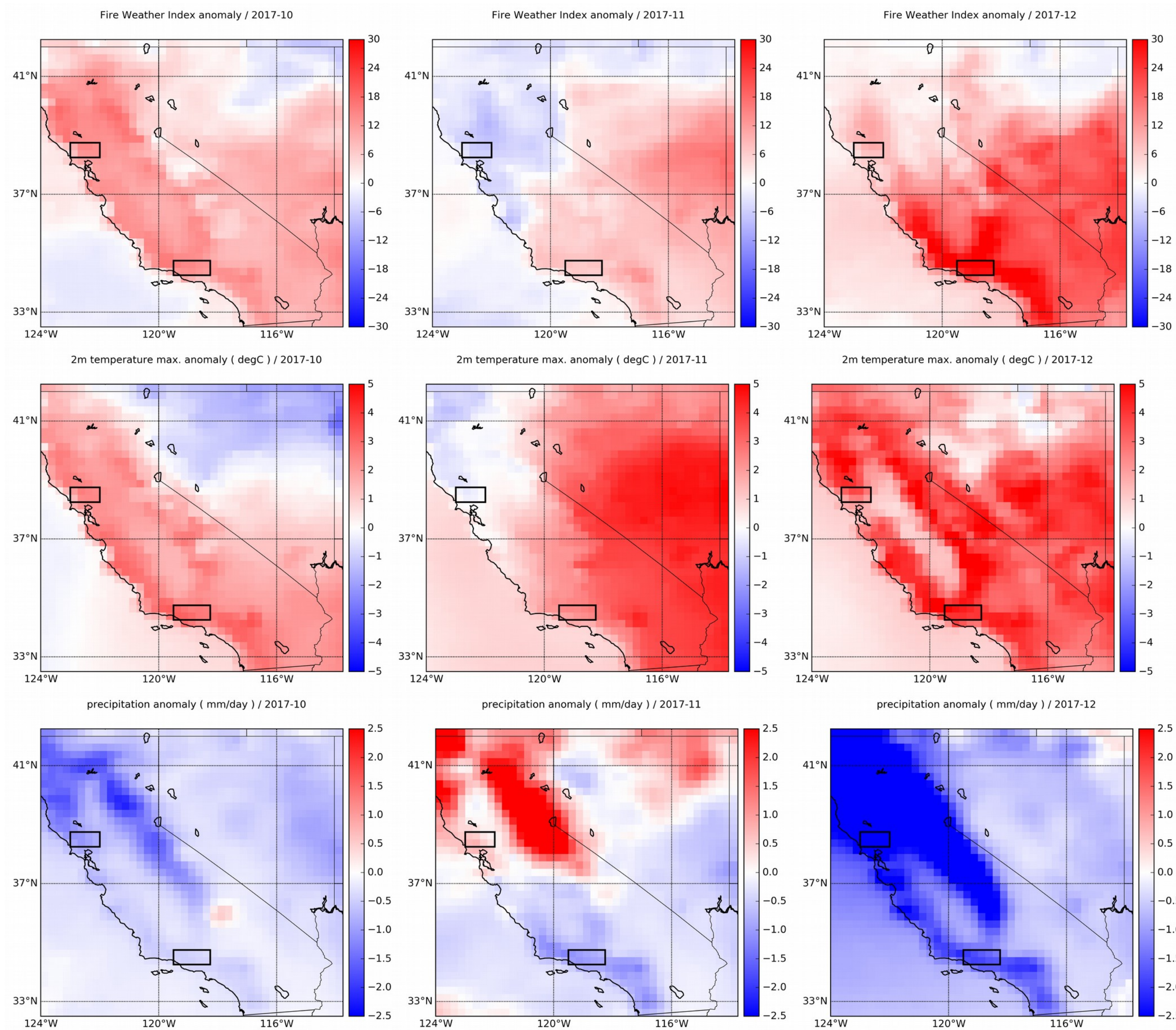
October | November | December

FWI

Temperature

Precipitation



FWI Conclusions

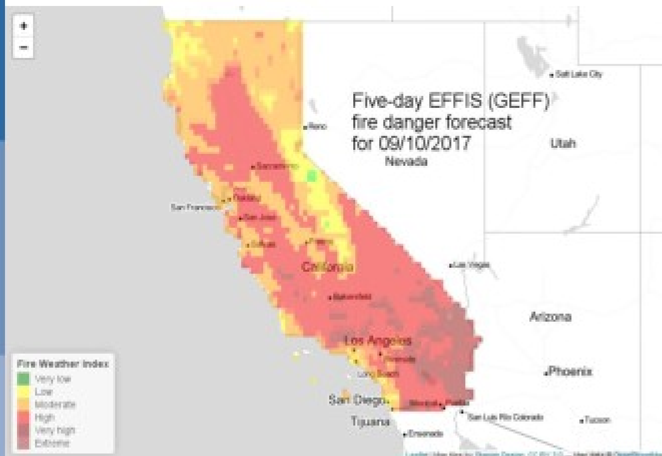
- Although the Santa Ana winds were important for fire spread as they fueled the flames, they were not stronger nor more frequent than other years.
- The anomalous warm and dry conditions which persisted for months were key factors in creating the extreme conditions.
- A long-term trend in temperature was detected, further work is require to quantify its relative importance and the likelihood that climate change will favor these conditions in the future.

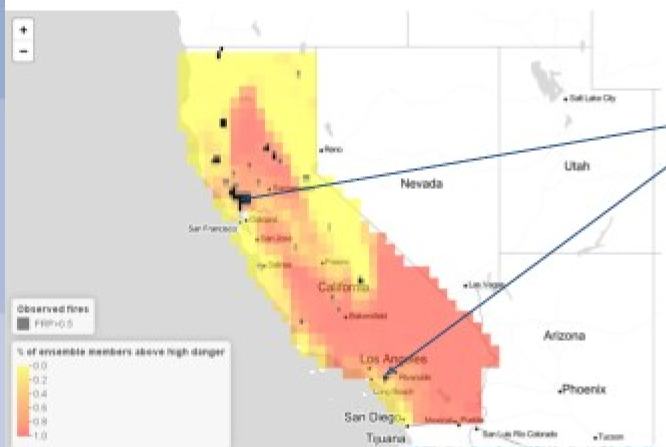
Future Work

- Using the CALIVER package to compute fire danger classes from observational data
- Analyzing the 2017 summer fires in Portugal and fall fires in Galicia, Spain
- Seasonal prediction of fire danger
  - Using operational seasonal prediction products (e.g. ECMWF S5) and EC-FIRE (GEFF)
  - Predicting frequency of days which extreme FWI a few months ahead
  - Can make authorities aware of extreme conditions and prepare ahead of time
  - Combined with reliable short-term forecasts (e.g. EFFIS/GWIS) this could prevent loss of property and life
  - Work focused on the 2017 wildfires in California, Portugal and Spain

Future Work

Another example: the California fire





California fire (8-11 October 2017)

The **2017 California wildfire season** was the most destructive wildfire season on record,which saw multiple wildfires burning across California. A total of 9,133 fires burned 1,381,405 acres (5,590.35 km^2), according to the California Department of Forestry and Fire Protection, including five of the 20 most destructive wildland-urban interface fires in the state's history.

State data showed that the large wildfires killed 43 people – 41 civilians and 2 firefighters - higher than the previous 10 years combined

Observed fires

Probabilistic information provided by the fire forecast Ensemble prediction system

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS 15

Source : Francesca Di Giuseppe (ECMWF)
https://cpo.noaa.gov/Portals/0/Docs/MAPP/Pdfs/DiGiuseppe.pdf

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Centro Nacional de Supercomputación

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Thank you!

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MARIE CURIE ACTIONS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 748750 "SPFireSD" - Seasonal Prediction of Fire danger using Statistical and Dynamical models

Daily input data

FWI

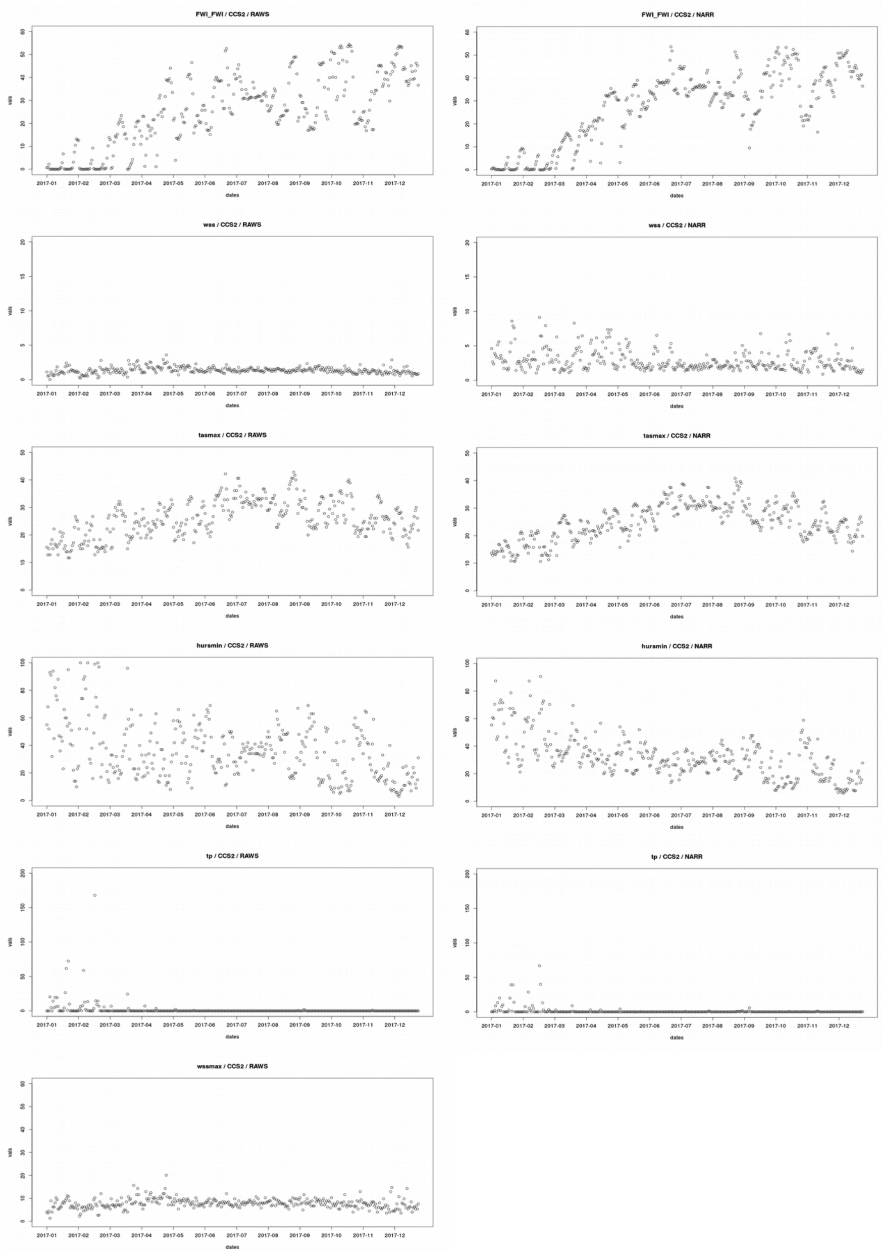
Average wind Speed (m/s)

Maximum Temperature (C)

Minimum Relative Humidity (%)

Precipitation (mm/day)

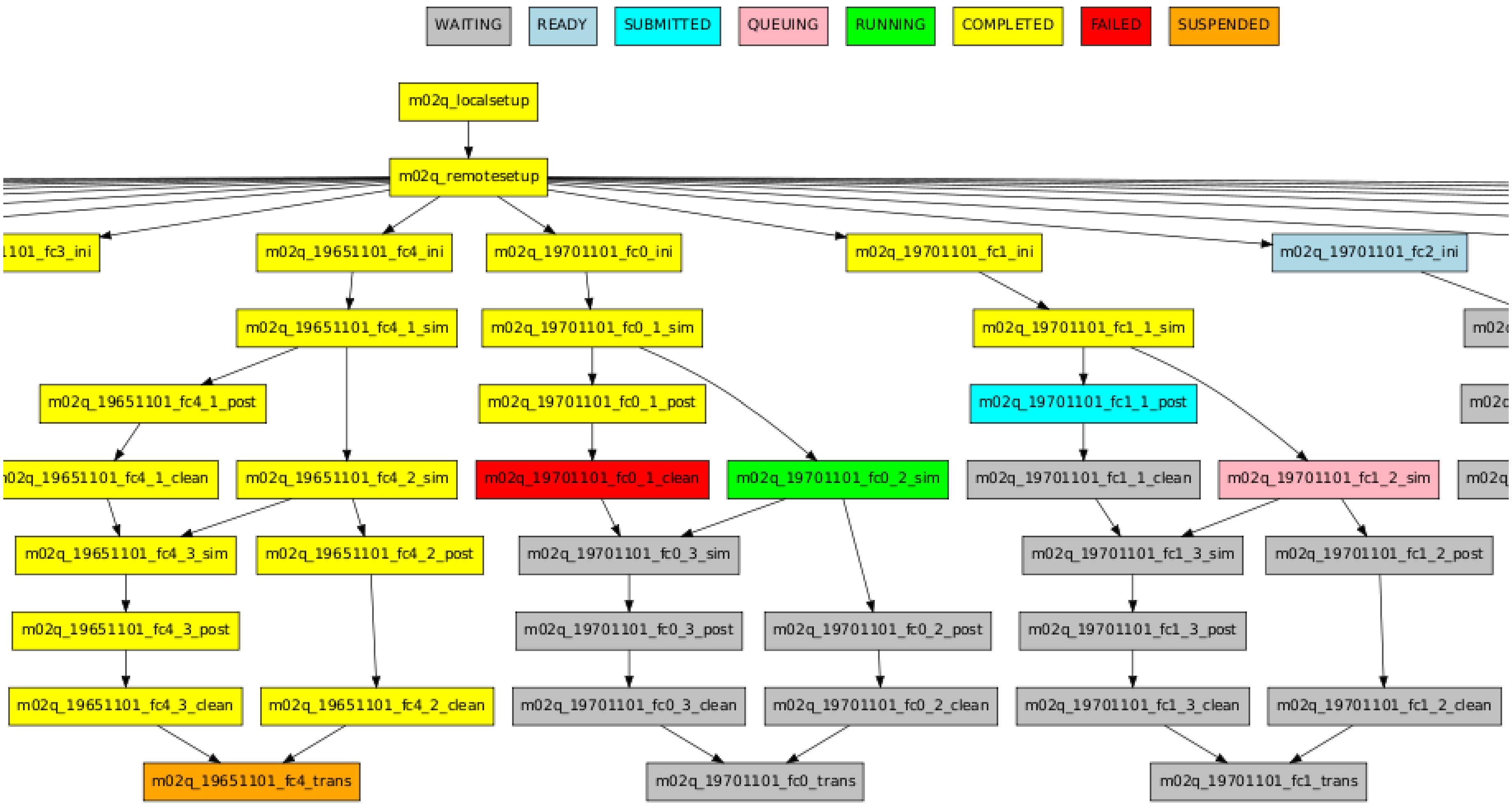
Wind speed gust (m/s)



Introduction

- The 2017 fire season in California was the costliest on record, with 18 Billion US$ in damages, and deadliest with 43 casualties on record
- In October, around the Napa valley in Northern California, the Tubbs fire was the most destructive in US history. Warm temperatures and strong winds are thought to be responsible for the severity of these wildfires.
- In December, Southern California was plagued by severe wildfires and the Thomas fire near Los Angeles became the largest in California history. It was thought to be fueled by sever Santa Ana winds and warmer than average temperatures.
- This works aims to study the important meteorological and climactic factors responsible for the extreme widlfire season of 2017 in California, using the Canadian Fire Weather Index computed from daily values of maximum temperature, minimum relative humidity, wind speed and precipitation computed from RAWS weather stations and ERA-Interim and NARR reanalyses.

Climate Prediction Workflow



Initial conditions for climate prediction

- Atmospheric initial conditions generated using FULLPOS for three different resolutions of IFS. FULLPOS conducts a physical interpolation and therefore ensures little model drift.
- We are investigating how to generate these without relying on prepIFS, open to suggestions!!!
- The initial conditions are prepared for many periods:
  - 1960 - 2015 using ERA-40 (1960-1978)
  - ERA-Interim (1979-2015)
  - ERA-Land (1979-2015) - forced by GPCP, replaces surface model fields
- 10-member (SST perturbation), Start dates each year in February, May, August, November

Initial conditions for climate prediction

- Ocean:
  - ORAS4 interpolated/extrapolated 5-member restarts in the configuration ORCA1L75 covering the 1958-2013 period, at ECFS ec:/c3y/restarts_ORAS4
  - Many more available, and more can be produced easily
- Sea Ice:
  - 5-member ORCA1 reconstructions
  - 1-member ORCA1 and ORCA025 reconstructions
  - 24-member ORCA1 reconstructions with sea ice data assimilation (done using NEMO or EC-Earth)
  - ORCA025 reconstruction under development
  - Work by F. Massonet and N. Fuckar